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VIRUS DISEASES OF BLACK RASPBERRIES

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W. HOWARD RANKIN

ABSTRACT

A synonymy of the raspberry virus disease names is given and the following names are recommended for the five virus diseases recognized: Leaf-curl alpha type, leaf-curl beta type, severe streak, mild streak, red (raspberry) mosaic, and yellow mosaic. The name mild mosaic may be retained for a small dot-like type of mottling, but its virus nature, if it is separable from red (raspberry) mosaic, is doubted.

The symptoms of the above-named virus diseases are given as they appear in black varieties of raspberries.

Results of inoculations, using the two known aphid vectors, are given. These results confirm previous work.

The rate of spread of yellow mosaic, mild streak, and red mosaic (including "mild mosaic") is given for an experimental planting containing the varieties Plum Farmer, Cumberland, and Ohio. Red mosaic is shown to be very rapid in its spread. Yellow mosaic spreads slowly, apparently due to the early dwarfing and death of the plants reducing the number of sources of spread. Mild streak spreads rapidly in the variety Ohio.

Correlation in the variety Plum Farmer between "mild mosaic" and red mosaic in the same plants indicates that they are phases of the same disease as shown by a susceptible variety. The Cumberland is an exception to most black varieties in that the necrotic symptoms are often suppressed to a point that they are scarcely detectable. The suppression of the necrotic symptoms in Cumberland is believed to explain the original description of "mild mosaic" on that variety as a distinct disease.

INTRODUCTION

Virus diseases of cultivated raspberries are not new troubles of this crop plant. They are merely newly recognized diseases which have been known to horticulturists for decades. Raspberry varieties have long been subject to "running-out", and they have been discarded as worth-

less and new varieties of more vigor substituted. It is now known that the virus diseases account for the "running-out" of varieties which otherwise are as stable as the varieties of other fruits that are vegetatively propagated.

Published accounts of the early recognition of virus diseases in raspberries appeared before their nature was understood. The name "leaf-curl" was given to a disease of raspberries in Minnesota by Green (5)[1] in 1895, and the name "yellows" was given to a mosaic of red raspberries found in the Hudson River Valley by Stewart and Eustace (9) in 1902. From that time the mosaic and leaf-curl types of diseases of raspberries were generally written about under the single name yellows. No progress was made in explaining the nature of the yellows disease or its control until 1920. By that time the virus diseases of potatoes had been sufficiently explained to suggest means of working with the large number of virus diseases soon recognized in other crop plants. The raspberry was one of the earliest to receive attention and the "yellows" was split into two separate diseases and named leaf-curl and mosaic. The fact that they were aphid transmitted and that roguing and the isolation of virus-free strains furnished practical means of preventing losses was soon established.

Since the first separation of "yellows" into two diseases, leaf-curl and mosaic, experience has shown that there are several distinct virus diseases. Differences of opinion as to the identity and limitation of symptoms of the several diseases have existed among workers. The grouping and names given below, it is hoped, will serve to standardize the nomenclature of these diseases.

SYNONYMY OF RASPBERRY VIRUS DISEASE NAMES IN THE DESCRIPTIVE LITERATURE

LEAF-CURLS.—First generally described by Green (5, 1895) as "leaf curl".

Virus 1. Leaf-curl alpha type.—First described by Melchers (6, 1914) as "raspberry curl or yellows" (in part); Rankin and Hockey (8, 1922) as "leaf-curl" (in part); Bennett (1, 1927) as "curl" (in part); Bennett (3, 1930) as "alpha-curl". It is commonly found in the variety Cuthbert and occasionally in other red varieties. It does not occur in black varieties. The range of this type is general; it is more or less serious in Ontario, Canada, and southward and westward. It is not important in New York.

Virus 2. Leaf-curl beta type.—First described by Melchers (6, 1914) as "raspberry curl or yellows" (in part); Rankin and Hockey (8, 1922) as "leaf-curl" (in part); Bennett (1, 1927) as "curl" (in part); Bennett

[1]Refers to Literature Cited, page 23.

(3, 1930) as "beta-curl". Confused with "leaf-curl" as known on Cuthbert until separated by Bennett (3, 1930). Occurs commonly in black varieties and to some extent in red varieties. Serious in northern Ohio and in southern Michigan; less prevalent elsewhere and rarely found in New York.

Virus 3. Severe streak.—First described by Wilcox (10, 1922) as "eastern blue-stem" (in part); Dodge and Wilcox (4, 1926) as "streak" (in part). Now recognized as the more injurious of two similar diseases confused under the name "streak". Occurs in black varieties only. Serious in northern Ohio, but not prevalent elsewhere. Occurs in the extreme western part of New York and is known there definitely only in the variety Black Giant.

Virus 4. Mild streak.—First described by Wilcox (10, 1922) as "eastern blue-stem" (in part); Dodge and Wilcox (4, 1926) as "streak" (in part). Confused with severe streak until the present time. Occurs in black varieties only. Found in northern Ohio, but much less prevalent than severe streak. Occurs in New York, particularly in the varieties Ohio and Kansas in central New York.

MOSAICS.—First generally described by Stewart and Eustace (9, 1902) as "yellows".

Virus 1. Red (raspberry) mosaic.—First described by Rankin and Hockey (8, 1922) as "mosaic" (in part), in red varieties; Dodge and Wilcox (4, 1926) as types of "mosaic" (in part), in black varieties; Bennett (1, 1927 and 2, 1929) as "red raspberry mosaic" and "mild mosaic", in black varieties (with possible exclusion of very mild types). The names "mosaic" and "red (raspberry) mosaic" have been used in all literature to the present time to include yellow mosaic in red and purple varieties. "Mild mosaic" was separated from "red raspberry mosaic" by Bennett (1, 1927) and is here recombined with red (raspberry) mosaic in black varieties. Generally prevalent in the variety Cuthbert and the Cuthbert types of red raspberries; less prevalent or unknown in other red varieties. Generally prevalent and serious in black varieties. The most serious of all the virus diseases in red and black raspberries in New York.

Virus 2. Yellow mosaic.—First described by Rankin and Hockey (8, 1922) as "mosaic" (in part), in red varieties; Dodge and Wilcox (4, 1926) as a type of "mosaic" (in part), in black varieties; Rankin (7, 1927) as "curly dwarf" in black varieties; Bennett (1, 1927) as "yellow mosaic" in black varieties. Yellow mosaic has been confused with and included with red (raspberry) mosaic in red and purple varieties in all literature until the present time. More generally prevalent in red and purple varieties than red (raspberry) mosaic, but in most varieties it is less serious. Generally prevalent and serious in black varieties. The most prevalent of all the virus diseases in red and purple varieties in New York and commonly found in black varieties.

Virus 3. Mild mosaic (in a more restricted sense than given by Bennett, 2, 1929).—It is doubtful if the small residuum after combining for the most part "mild mosaic" with red (raspberry) mosaic represents a virus disease. The small dot-like type of "mild mosaic" is the only type not referred here to red (raspberry) mosaic. It is typically shown in black and purple varieties. A similar type of mottling definitely correlated with low

temperatures is found in raspberries. It seems doubtful if there exists a distinct virus disease that should be called mild mosaic. This statement includes the so-called "mild mosaic" in purple varieties in which it is believed that all types of virus mottling are referable to either red (raspberry) mosaic or to yellow mosaic.

The above synonymy of names for the virus diseases is more fully explained in the discussions based on the field work reported in this bulletin. The principal changes as to the delimitations of the several diseases here reported are to separate mild streak from severe streak as a distinct virus disease, to separate yellow from red (raspberry) mosaic in red varieties, and to combine with red (raspberry) mosaic those phases of the previously and broadly described "mild mosaic" on black varieties, excepting the small, dot-like type of so-called mild mosaic. All of the above-named virus diseases are known to occur in black varieties of raspberries, except leaf-curl alpha type (leaf-curl, virus 1).

SYMPTOMS OF VIRUS DISEASES

LEAF-CURL BETA TYPE

Leaf-curl does not occur except sporadically in black raspberries in New York and is found only rarely on red and purple varieties. Leaf-curl beta type is a serious disease of black raspberries in northern Ohio and in Michigan. It is a potential disease of the future, at least for western New York where a large acreage of black raspberries exists at no greater distance than 100 miles from fields in Ohio in which it is serious. As a precaution, leaf-curl that may appear in red or purple varieties in western New York should be promptly rogued on suspicion that it may be the type that is a menace to black varieties. Black varieties known to be particularly susceptible to leaf-curl should be grown only in well-protected areas in western New York. Plantings of the black variety Cumberland are rapidly and seriously damaged by leaf-curl in northern Ohio. Plum Farmer is believed to be resistant. Also, it would be unwise to plant the red variety Cuthbert close to plantings of black varieties in western New York because Cuthbert, particularly, serves as a breeding place for leaf-curl of both types. Other red varieties are much more klendusic[2] to leaf-curl.

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[2] The term "klendusic" was defined and used in Bulletin No. 543 of this Station on "Mosaic of Raspberries". A klendusic variety is one in which a given disease spreads slowly; another variety which is not klendusic is one in which the disease spreads rapidly. The klendusity of a variety to a given disease is no indication of its susceptibility or resistance to that disease for these are expressions of the reaction of the plant after infection begins, while klendusity refers to the rate at which effective inoculation occurs in the variety.

Of the two leaf-curl diseases only the one named leaf-curl beta type occurs in black raspberries. It has been experimentally transferred by Bennett (3) to red and purple raspberries, showing that it may exist in these as well as in black varieties. To what extent this leaf-curl does exist naturally in red and purple varieties is not known. The leaf-curl commonly found in Cuthbert and other red varieties is the alpha type and is not transmissible to black varieties. Thus, it may often happen in the sections where leaf-curl of red varieties is prevalent that black varieties growing alongside the reds escape infection. The two types of leaf-curl cannot be separated on red varieties by any differences in the symptoms.

Leaf-curl of both types is easily recognized. The leaves on the suckers and the fruiting canes are much darker green than normal and the midvein of the leaflets bends downward thruout its length. A similar bending of the main lateral veins causes a downward curling of the entire margin of the leaflets. The tissue between the veins arches upward and is crimped along the veins. The leaves of the fruiting laterals rarely show the extreme curling, altho the arching of the tissue between the veins, the crimping along the veins, and the shining appearance of the upper leaf surface are marked. The leaf deformation on the new canes usually becomes more pronounced as the season advances, until the tip of the cane is stunted and it ends in a few small, light yellowish green, and severely curled leaves. Such canes, if infected early in the season, do not reach normal height. The fruiting laterals on a diseased cane are short, upright in habit, and the leaves are small, dark green, and more or less deformed. Frequently, the tissue midway between the veins loses its green color and becames blanched or slightly bronzed. This type of mottling is easily distinguished from that which is characteristic of the mosaic diseases. The new canes formed the year after infection are much shorter than normal. After three or four years, the new canes are stunted to such an extent that they are usually only about a foot high. Black raspberries soon die, but red varieties persist and send up new dwarfed canes for many years. The fruit which develops on a plant affected with leaf-curl is mostly small, has very little pulp, and is lacking in flavor.

Leaf-curl is recognizable very soon after the leaves appear on the fruiting laterals in the spring. The aphid that carries the leaf-curl virus is present on the plants as soon as the leaves unfold. Affected plants should be rogued as early in the season as possible.

SEVERE STREAK

Streak was first described under the name of "eastern blue-stem" by Wilcox (10, 1922). It is a serious disease of black varieties in northern Ohio, and most of the investigations on it have been done in that region. Streak, while evidently a virus disease, has never been experimentally transmitted to healthy plants and the insect carrier is unknown. As early as 1923 a disease of black varieties was found in New York which was similar to streak, but less severe in its effect on the plant. This disease is now recognized as a distinct virus disease both in northern Ohio and in New York. The names severe streak and mild streak are suggested to distinguish them.

Severe streak is not prevalent in New York. It has been recognized only in the extreme western part of the State in a single variety, locally known as the Black Giant. Because of the damage done by severe streak in this variety its cultivation is being abandoned in that section.

Symptoms are not pronounced during the season in which infection occurs. The new canes are slightly less vigorous and the tip leaves in midsummer show a tendency for the ends of the leaflets to be bent downward sharply. The berries on such newly infected bushes may show a tendency to be retarded in development. The year following infection by severe streak definite symptoms are shown. The foliage of the fruiting canes is curled, the petioles are short, and the internodes on the fruiting spurs are foreshortened. The curling of the foliage is due to an arching downward of the midribs of the leaflets and a general cupping of the leaflets. The color of the leaves is slightly darker green than normal and the leaves are smaller. The tips of the leaves of new canes are decidedly recurved in midsummer. There is no mottling of the leaves that has been definitely associated with severe streak, altho a slight indication of a color pattern is sometimes found. Bluish markings on the canes are a constant and conspicuous symptom of this disease. The markings consist of dark blue or violet-blue dots, spots, or longitudinal stripes similar to pencil markings irregularly placed. These blue markings are usually most abundant near the base of the new canes, but may occur on the branches of the new canes or on the fruiting spurs. The general appearance of the plant is changed to that suggesting leaf-curl. Individual bushes decline in vigor in two or three seasons to the extent that they are severely dwarfed. The fruit on such bushes is very inferior soon after the bush shows definite symptoms.

MILD STREAK

Mild streak, as its name suggests, is a disease which shows all the characters described above for severe streak but in an attenuated form. The effect on the plant in most cases is not serious. The curling of the foliage is often only suggestive of streak and the cane markings may be absent or very few in number. The strength of symptoms that are developed depends somewhat on the seasonal conditions, varying from very slight to pronounced. But in no case are the symptoms expressed to the degree that the plants are severely dwarfed. They continue to grow to almost normal size and bear crops of fruit. The fruit is much more affected, however, than the appearance of the canes would suggest. The fruit seems to be halted in its development, the drupelets remaining under developed with bloom showing between them. Such fruit is dry and "seedy", and crumbles. It may be said, therefore, that while mild streak does not affect the vigor of the bush to a great extent, the crop is materially injured and the disease is important because of this effect.

Mild streak is more or less prevalent in central and western New York, particularly in the variety known in this region as Ohio and in the variety Kansas.

RED (RASPBERRY) MOSAIC

Within two weeks after a healthy Plum Farmer plant is inoculated with the virus of red mosaic, symptoms may become apparent in the tips of the new canes. Small water-soaked areas appear in the portion of the cane on which the new leaves are expanding and enlarging. Similar discolored areas develop on the petioles of the enlarging leaves. The tip of the cane usually makes no further growth and it becomes variously distorted. The water-soaked areas in the meantime become more extensive and turn to a deep blue color. The affected cane tips and leaves are turgid and "snap" upon bending. In about 10 days after the symptoms first appear the entire tip of the cane and its leaves die. The above description applies particularly to vigorously growing new canes of "creeper" plants (plants in their first year) and unpruned new canes of older plants directly inoculated by aphids in June or July. The tips of other new canes of the same plant may or may not show similar symptoms. All of the tips of a small plant usually die during the same season and the plant either succumbs the following spring or persists as a dwarf with short rosetted new canes for a season or two. Such dwarf canes show the blue-marked tips and leaf petioles during July.

Recently inoculated older plants, after showing the symptoms in the tip of a new cane or in the tips of laterals growing from a pruned new cane, do not follow any general rule. The original infected tip may be the only sign of red mosaic in the plant for the remainder of the season. Usually, several lateral tips from the same cane will show slight symptoms at least. In the next and succeeding years all of the canes of the individual plant react uniformly, but there is extreme variation shown in different plants. In plants which react most severely the canes are mostly dead by the next spring. Any laterals that are formed are short and the small leaves are rosetted and usually mottled. Practically no fruit is borne on such laterals. The new canes of such plants are usually dwarfed and rosetted. The leaflets in the rosette are larger, broader, and darker green than normal and usually do not show mottling.

The large majority of plants the year after infection show a less severe reaction than described above. During the first stages of development of the fruiting laterals growth is normal, but toward the tip the internodes are foreshortened to a variable degree. In some plants the tips of the fruiting laterals are a tight rosette of leaves and fruit. The leaves in the fruiting-lateral rosette are changed in form to a marked degree. The leaflets are much broader and larger. Also, they are darker green, altho they may be strongly mottled and wrinkled. From this extreme reaction all variations are shown in different plants to a condition that suggests slight rosetting which is mainly due to the shortening of the fruit pedicles. In the variety Plum Farmer, to which this description applies, the leaves of the fruiting laterals show a type of mottling that is characteristic for red mosaic in this variety. The mottling is visible in May and June at the same time that typical "mild mosaic" is most apparent in the variety Cumberland. The yellow areas vary from small, dot-like mild mosaic to larger types. They are irregularly scattered and may show no relation to the veins. This type of mottling is constant enough to make it one of the most dependable characteristics for roguing the Plum Farmer variety for red mosaic.

Many Plum Farmer plants which have shown definite necrotic symptoms of red mosaic one season fail to react as markedly in the second season, as has been described above. The rosetting of the fruiting lateral may be absent and the tips of the new canes and their laterals may "grow thru" the necrotic effect. In such cases of "growing thru" the tip does not die. The water-soaked and blue areas may appear on the cane or only on the petioles of the unfolding leaves and then the

tip grows on normally. The leaves in the region that shows the characteristic effect of red mosaic remain small and are curled downward. The petioles of these small leaves are "brittle". After once growing thru this stage in early July no further effects are shown during the remainder of the growth that season. There seems to be a tendency for this characteristic to be repeated in these plants the following year. The laterals from the new canes after pruning seem to have a greater tendency to "grow thru" the necrotic symptoms than do the unpruned canes. Many cases have been noted where the symptoms produced by red mosaic are very obscure, being confined to one or two small leaves on each lateral cane. The frequency of occurrence of such obscurely affected plants in the experimental planting points to the fact that a large number of affected plants will not be easily detected when roguing a commercial planting. Likewise, the grower will not be inclined to remove such plants, and for these reasons only the most expert inspection and roguing of Plum Farmer plantings may be expected to reduce the amount of red mosaic to a minimum. This error in depending upon necrotic symptoms for roguing can be avoided by using the early leaf mottling symptoms in the leaves of the fruiting laterals which have been found to mark definitely all infected plants.

YELLOW MOSAIC

Yellow mosaic is a distinct and easily recognized disease on black varieties. It was first recognized in black raspberries, but has only recently been segregated from red mosaic on red and purple varieties. Yellow mosaic is not as rapid spreading in black varieties as is red mosaic, but it is more destructive to the affected plants. The plants are severely dwarfed soon after infection. The fruiting laterals and leaves are more upright than normal. The foliage is distinctly yellow. The leaflets are longer and narrower than normal and variously distorted and curled. Most of the area of a leaflet is either whitish or yellow with a few areas of puckered green tissue intervening. All parts of the plant are "brittle" as in red mosaic, due to the turgidity of the tissues. New infections are shown very markedly by the distinct yellow blotching of the foliage in midsummer on canes which previously developed normal leaves. The fruit is worthless on plants affected by yellow mosaic.

Yellow mosaic is prevalent in black raspberries in New York, but it does not occur in as large percentages as does red mosaic. Most plantings of red and purple raspberries contain a small or large percentage

of plants affected by yellow mosaic, altho it may not be conspicuous; and these serve as a source of spread to adjacent black raspberry plantings.

MILD MOSAIC

Mild mosaic is a name that may be retained for a type of mottling of raspberry foliage which, while apparently of a virus nature, has not been definitely proved as such. Opinion has varied as to the range of symptoms shown by "mild mosaic", and originally all mild types of mottling which were apparently distinct from other known virus diseases were included together under this name. Such a classification has been recognized for some time to be very likely erroneous. It is now known that the mottling in red varieties previously thought to be "mild mosaic" is in reality yellow mosaic as expressed in a variety resistant to this virus. "Mild mosaic" as shown in Columbian and other purple varieties will, it seems, be eventually connected with red mosaic. Most of the symptoms given by Bennett (1, 2) in describing and delineating "mild mosaic" from red mosaic in black varieties are here included under red mosaic because of the strong indication that they are phases of the same disease.

The symptoms of mild mosaic that remain to be explained as to cause consist in very small, round dots of yellow or yellow-green distributed mainly alongside the veins. Certain groups of leaves show these symptoms, while others on the same cane do not. This type of mottling is so often correlated with the more diffuse types that the writer doubts if any real separation is possible and is inclined to include whatever part of such mottling that may be of a virus nature with red mosaic. There are mottling symptoms produced in red, purple, and black raspberries in the earliest leaves unfolded that are definitely due to weather conditions. This mottling may at times assume a character very much like suppressed yellow mosaic in red varieties (particularly in the varieties June and Ontario) and suppressed red mosaic in black varieties.

RESULTS OF INOCULATIONS

Accurate results in transferring a virus disease from a diseased plant to a healthy one are difficult to obtain in the field when so many factors are uncontrolled. Plants free from all virus diseases are difficult to select, and unless caged in aphid-proof coverings are liable to chance infection. Such covering of the plants is not only costly for a large number of plants, but also is not a sure protection from chance infection

over a period of two seasons. Furthermore, the plants so caged develop abnormally and may not display the typical symptoms of the disease. The inoculations reported here were made on unprotected plants. The results are adequate in general and support the observational studies.

The principal conclusions obtainable from the data are that apparently virus-free red raspberries do not carry any virus that is transferable to black raspberries; that red mosaic is transferred from red to black raspberries by the aphid *Amphorophora rubi;* that red mosaic is transferred from black to black raspberries by the aphid *Am. rubi,* but is not transferable by *Aphis rubiphila;* that yellow mosaic is transferable from black to black raspberries by the aphid *Am. rubi,* but is not transferable by *A. rubiphila;* that mild mosaic of the small yellow dot type is not transferable from black to black raspberries by the aphid *Am. rubi;* and that mild streak is not transferable from black to black raspberries by the aphid *Am. rubi.* These results are similar to those reported by Bennett (1), except as to mild mosaic, which may be explained on the basis of difference in interpretation of the term "mild mosaic".

In Table 1 are given the details of the several series of inoculations. At the time of making the inoculations the incidence of the various diseases was small. Rows for each type of inoculation were chosen which seemed to be adequately protected by being distant from chance infection. The comparison in the last two columns of Table 1 between the percentage of the virus disease occurring in the inoculated population and in the non-inoculated population of the same row gives an approximate means of judging the results of the inoculations.

The inoculations were made by transferring one or more of the aphids from colonies on caged plants showing the symptoms of a given virus disease to the unfolding leaves of the new canes of healthy plants. The aphids were carried on the foliage of the original host and transferred by means of a camel's hair brush.

RATE OF SPREAD OF VIRUS DISEASES

The inoculations were made in certain rows of the experimental planting in the spring of 1927 before it was decided to use the planting for determining the rate of spread of the different diseases. At that time a small percentage of diseased plants was recognized in the rows adjoining a Cuthbert planting, but the remainder appeared free from virus diseases. A detailed study of the symptoms expressed by the

TABLE 1.—RESULTS OF INOCULATIONS, USING APHID VECTORS.

VIRUS IN SOURCE PLANTS	VARIETY OF SOURCE PLANTS	APHID SPECIES	NUMBER OF APHIDS TRANSFERRED	PLANTS INOCULATED		NUMBER OF PLANTS REMAINING HEALTHY	DISEASES PRESENT IN INOCULATED PLANTS ONE YEAR LATER				INOCULATED PLANTS		NON-INOCULATED PLANTS IN SAME ROW	
				Variety	Number		Mild mosaic,† number	Red mosaic, number	Yellow mosaic, number	Mild streak, number	Per cent	Virus	Per cent	Virus
None	Cuthbert	*Am. rubi*	5	Cumberland Plum Farmer	20	17	1	2	0	0	10	Red mosaic	7	Red mosaic
None	Sunbeam	*A. rubiphila*	5+	Cumberland Plum Farmer	10	10	0	0	0	0	0		0	
Red mosaic*	King	*Am. rubi*	1-5	Cumberland							{17	Red mosaic	{14	Red mosaic
				Plum Farmer	12	5	3	2	2	0	{17	Yellow mosaic	} 0	Yellow mosaic
Red mosaic	Owasco	*Am. rubi*	1-5	Cumberland Plum Farmer	15	3	2	9	1	0	60	Red mosaic	9	Red mosaic
Red mosaic	Plum Farmer	*Am. rubi*	1-5	Cumberland Plum Farmer	14	4	1	9	0	0	64	Red mosaic	7	Red mosaic
Red mosaic	Plum Farmer	*Am. rubi*	1-5	Cumberland	5	2	3	0	0	0	0	Red mosaic	0	Red mosaic
Red mosaic	Plum Farmer	*A. rubiphila*	Several	Plum Farmer	21	18	0	3	0	0	14	Red mosaic	15	Red mosaic
Yellow mosaic	Plum Farmer	*Am. rubi*	1-5	Cumberland Plum Farmer	11	1	1	1	8	0	73	Yellow mosaic	0	Yellow mosaic
Yellow mosaic*	Cumberland	*Am. rubi*	2-7	Cumberland Plum Farmer	11	8	1	2	0	0	0	Yellow mosaic	0	Yellow mosaic
Yellow mosaic	Plum Farmer	*A. rubiphila*	Several	Cumberland Plum Farmer	21	18	0	3	0	0	0	Yellow mosaic	0	Yellow mosaic
Mild mosaic†	Cumberland	*Am. rubi*	1-many	Cumberland	11	7	3	1	0	0	27	Mild mosaic	40	Mild mosaic
Mild mosaic†	Cumberland	*Am. rubi*	1-5	Plum Farmer	23	15	0	8	0	0	0	Mild mosaic	0	Mild mosaic
Mild streak	?	*Am. rubi*	1-3	Plum Farmer	7	3	4	0	0	0	0	Mild streak	0	Mild streak
Mild streak	?	*Am. rubi*	Several	Plum Farmer	13	7	2	3	1	0	0	Mild streak	0	Mild streak
Mild streak	?	*Am. rubi*	1-5	Plum Farmer	28	19	0	8	1	0	0	Mild streak	0	Mild streak

*Immediately after these transfers were made a violent wind and rain storm began.

†Mild mosaic as here used includes principally the small dot-like type and also other types of mild mosaic in which no confirmatory evidence of red mosaic was found in the plant.

diseased plants was begun the same season, and by fall a much higher percentage of each of the diseases as then understood was found to exist in the planting. The series of inoculations which resulted in infection were confined to rows 6 to 11. Altho several of the series of inoculations were made in other rows, they gave negative results and were not a factor in increasing the spread of the diseases in these rows.

TABLE 2.—PERCENTAGES OF THE VIRUS DISEASES IN SECTIONS OF THE PLANTING AND THE UNIFORMITY OF INCIDENCE OF THE DISEASES IN ROWS 14 TO 29 IN WHICH THE RATE OF SPREAD WAS STUDIED.

GROUPING OF ROWS	INOCULATIONS MADE IN 1927	HEALTHY	"MILD MOSAIC"*	RED MOSAIC†	YELLOW MOSAIC	MILD STREAK
		1927 Average Percentages				
1-5	None	86.6	10.6	2.5	0.0	0.3
6-11	Many; large number positive	74.2	7.1	15.7	1.5	1.5
12-13	None	62.3	25.4	6.6	0.0	5.7
14-19	None	68.3	22.9	6.0	0.4	2.4
14-29	Many; but all were negative	70.1	18.2	8.4	0.3	3.0
		1928 Average Percentages				
1-5	None	76.6	17.9	5.1	0.0	0.4
6-11	Many; large number positive	67.9	16.2	10.4	4.5	1.0
12-13	None	43.1	41.2	11.8	0.0	3.9
14-19	None	43.2	26.4	26.4	1.6	2.4
14-29	Many; but all were negative	47.2	21.6	25.7	1.7	3.8
		1929 Average Percentages				
1-5‡	None	——	——	——	——	——
6-11‡	Many; large number positive	——	——	——	——	——
12-13‡	None	——	——	——	——	——
14-19	None	32.3	15.9	41.4	3.6	6.8
14-29	Many; but all were negative	32.8	14.6	38.7	2.5	11.4

*Plants showing any type of leaf mottling but no necrotic symptoms.
†Plants showing necrotic symptoms.
‡Plowed out in 1928.

In Table 2 are given the percentages of plants affected by the various diseases arranged in groups of rows. The figures show that during the two years 1927 and 1928 the successful and unsuccessful series of inoculations had not affected the natural incidence of the diseases in rows 14 to 29. In the fall of 1928, rows 1 to 13 were plowed out, altho they still contained a smaller percentage of diseased plants than the remainder of the planting. It will be noted in Table 2 that the percentages of the different diseases are uniform in each year for the block con-

taining rows 14 to 19 as compared with the entire block of rows 14 to 29. In the study of the rate of spread, only the data for rows 14 to 29 of the original planting have been considered. The planting consisted of a mixed lot of varieties haphazardly scattered. In 1927, there were 373 Plum Farmer, 190 Cumberland, 38 Ohio, and 68 unknown (believed to be largely Gregg) in rows 14 to 29 of the planting.

YELLOW MOSAIC

The symptoms of yellow mosaic are definite in different types of seasons and usually there is no difficulty in identifying it. One case of combined mild streak and yellow mosaic was observed in the planting. Apparent cases of combined red and yellow mosaic were suspected in some cases, but the symptoms of yellow mosaic seem to predominate definitely to the extent that they would be classified as yellow mosaic. Therefore, the amount of yellow mosaic in the planting was not subject to errors of determination or masking.

TABLE 3.—PERCENTAGE OF THE VIRUS DISEASES IN ROWS 14 TO 29 AS SHOWN BY THE POPULATION OF THE VARIETIES PLUM FARMER AND CUMBERLAND.

YEAR	PLANTS ALIVE, NUMBER	HEALTHY, PER CENT	RED MOSAIC, PER CENT*	YELLOW MOSAIC, PER CENT	MILD STREAK, PER CENT	RED MOSAIC DIVIDED	
						Mild symptoms, per cent†	Necrotic symptoms, per cent
			Plum Farmer				
1927	373	80.7	18.2	0.3	0.8	7.2	11.0
1928	376	54.0	43.3	1.6	1.1	4.8	38.5
1929	357	38.1	52.4	2.8	6.7	1.1	51.3
			Cumberland				
1927	190	55.8	43.1	0.0	1.1	41.0	2.1
1928	191	37.7	58.1	1.6	2.6	53.9	4.2
1929	178	23.0	64.1	2.2	10.7	44.4	19.7
			Entire Planting‡				
1927	669	70.1	26.6	0.3	3.0	18.2	8.4
1928	662	47.2	47.3	1.7	3.8	21.6	25.7
1929	596	32.8	53.3	2.5	11.4	14.6	38.7

*Including "mild mosaic" leaf mottling.
†Plants showing "mild mosaic" leaf mottling, but no necrotic symptoms.
‡Including Ohio and unknowns.

The rate of spread of yellow mosaic was not rapid, 0.3 per cent being present in 1927 and 2.5 per cent in 1929 (Table 3). No yellow mosaic was found in the Ohio variety, but the population of this variety was so small and the total amount of yellow mosaic likewise so small that it is not definitely indicated that the Ohio is immune. Since mild streak

spread to the extent of 71 per cent in Ohio, it seems that the fact that no yellow mosaic showed in this variety indicates that it is highly klendusic to yellow mosaic but lacks klendusity to mild streak. In the population of Plum Farmer and Cumberland the rate of spread of yellow mosaic was about the same, there being 2.8 per cent in the Plum Farmer and 2.2 per cent in the Cumberland in 1929. These two varieties appear to be more klendusic to yellow mosaic than many varieties of red raspberries, but it is doubted that this is a case of real klendusity. It seems more likely that the severe dwarfing and early death of the affected plants may account for the slow rate of spread of yellow mosaic in black raspberries by eliminating the sources of infection. Inoculations show that it is as readily transmitted as red mosaic in black varieties.

MILD STREAK

The identification of mild streak in 1927 was difficult due to the indefinite symptoms that were shown by the affected plants. Therefore, the records as to the location of the plants affected by mild streak and the percentage of this disease in 1927 are subject to considerable error. Only a small amount of mild streak was found in 1927 in the varieties Plum Farmer and Cumberland, *viz.*, 0.8 and 1.1 per cent, respectively, but in the small population of the variety Ohio about 32 per cent were affected. In Table 3 are shown the percentages for the three seasons. Taking the planting as a whole mild streak increased from 3 per cent in 1927 to 11.4 per cent in 1929. The Plum Farmer plants showed, in 1929, 6.7 per cent; the Cumberland, 10.7 per cent; and the Ohio, 71.4 per cent (not shown in the table). The rate of spread was clearly shown to be much more rapid in the variety Ohio than in the other two varieties.

Mild streak was easily identified in 1928 and 1929. Combinations of red mosaic and mild streak were recognizable in cases where the plant was not too severely affected by red mosaic. Thirteen plants, 11 of which were the Plum Farmer variety, showed combined red mosaic and mild streak in 1929. Eight of these plants were in a small area near a plant which was affected by both diseases in 1928 and seemed to indicate that the double infection resulted from this plant as a source of spread. Six of the eight plants showing double infection stood within 30 feet of the apparent source.

Since the mild streak inoculation tests with both of the raspberry aphids were negative and since no one previously had succeeded in

proving the disease transmissible by any vector used in inoculation experiments, the spread of mild streak was plotted in an attempt to learn the relation between sources of infection and the position of newly affected plants. Previous studies of red mosaic have shown that plants adjacent to diseased plants become infected in large numbers and that scattering infections are less likely to occur. In the experimental black raspberry planting there were 19 affected plants in 1928 from which mild streak could be transmitted to adjacent plants on one or both sides in the row. In 10 of the 19 cases such possible chance infection did result, as shown in 1929. There were 13 locations where there were adjacent plants on both sides of the affected plant, but in no case did both adjacent plants become infected, altho one of the two adjacent plants became infected in seven cases and neither in six cases. The evidence from such a correlation is not conclusive but shows that a much higher percentage of infection occurred in plants immediately adjacent to previously diseased sources of possible infection than occurred over the entire planting. Briefly stated, 31 per cent of the plants adjacent to possible sources of infection showed mild streak in 1929, while the remainder of the newly affected plants was 9.7 per cent of the entire population.

Assuming a larger area of possible spread of mild streak to include all plants at a distance of less than 10 feet from the possible sources known in 1928, a similar correlation was found to apply. Of a total of 58 plants showing mild streak for the first time in 1929, 28 (48 per cent) stood within 10 feet of known centers of spread and 30 (52 per cent) were located at distances greater than 10 feet. The area involved in these centers of local spread, where 48 per cent of the infection occurred, was not more than one-fourth of the total area of the planting. By including all known sources of mild streak spread which had existed in either 1927 or 1928, or in both years, some of these plants having died before 1929, the correlation was even greater, only 22 of the 58 newly affected plants in 1929 being located further than 10 feet from possible centers of spread and only 13 more than 20 feet distant from these sources. Without attempting to analyze the correlation more accurately, it seems that the chance of plants standing adjacent to mild streak or within 10 feet of affected plants being more likely to show mild streak in one or two seasons is about three times greater than the chances of plants which stand further than 10 feet from an affected plant. This fact furnishes additional evidence that mild streak is a transmissible disease and similar in its manner of spread to the other proved virus diseases.

RED MOSAIC

The identification of red mosaic in the planting was not as accurately made in 1927 as it was in the following two seasons. The first season only the more pronounced necrotic symptoms in the tips of the new canes were used, but in 1928 and 1929 the plants were carefully examined for all evidence of dwarfed leaves and the markings on the petioles. The dwarfing and rosetting of fruiting laterals were more carefully examined in these years also, but in no case were slight symptoms as shown by fruiting lateral development used for diagnosis unless they were accompanied by corroborative necrotic symptoms on the new canes. The correlation of the mottling symptoms on fruiting lateral foliage in the Plum Farmer variety with the occurrence of definite red mosaic symptoms was recognized in 1928. The data on "mild mosaic" were kept separate and the percentages showing "mild mosaic" leaf mottling and no necrotic symptoms are given in Table 3.

Excluding "mild mosaic" for the present and using only the more pronounced and definitely recognized symptoms of red mosaic, it will be seen from Table 3, last column, that in three years red mosaic increased in the Plum Farmer population from 11 per cent in 1927 to 51.3 per cent in 1929. These figures corroborate frequently observed cases of rapid spread of this mosaic in plantings of Plum Farmer. In the Cumberland population the amount of red mosaic as determined by the necrotic symptoms increased from 2.1 per cent to 19.7 per cent in the three seasons. In the small Ohio population no red mosaic was found in 1927 and only one plant of this variety definitely showed the necrotic symptoms of this mosaic in 1929. In the planting as a whole the amount of red mosaic as shown by necrotic symptoms was for the three years, respectively, 8.4, 25.7, and 38.7 per cent.

If these data on rate of spread of red mosaic as determined by necrotic symptoms are correct, the inference would be that Cumberland is moderately klendusic and the Ohio highly klendusic to mosaic. Yellow mosaic and mild streak spread at about the same rate in Plum Farmer and Cumberland, while mild streak spread rapidly to the few Ohio plants present, showing that the factor for spread in these diseases operated equally or more rapidly in Cumberland and Ohio than in Plum Farmer. Greater klendusity to red mosaic in Cumberland and Ohio as based on necrotic symptoms is not believed to be a correct inference. The explanation of the varietal difference is believed to be due to the greater resistance (masking of the necrotic symp-

toms) of these varieties. In the following discussion of "mild mosaic", reasons for considering this mosaic to be merely a phase of red mosaic are advanced. The correlation between "mild mosaic" and red mosaic in Plum Farmer is so striking (and the same correlation holds true for most varieties of black raspberries) that the identity of "mild mosaic" and red mosaic is considered established. The identical symptoms of "mild mosaic" in the variety Cumberland were not found to be so uniformly correlated with necrotic symptoms of red mosaic, but it is reasonable to believe that this is due to greater suppression which leads to infrequent showing of the necrotic type of symptoms.

Combining the "mild mosaic" and necrotic phases of red mosaic, as shown in Table 3, the rate of spread of red mosaic in two years is, for Plum Farmer, from 18 to 52 per cent; for Cumberland, from 43 to 64 per cent; and for the planting as a whole, including other varieties, from 26 to 53 per cent. When it is considered that these percentages are for the increase of this disease for the second and third years after planting, the importance of this disease is clearly shown. Similar rates of increase for red mosaic in new plantings of Plum Farmer have been noted in New York. Unless the stock is practically free from diseased plants and the surrounding territory free from other raspberries containing this disease such rapid rates of increase may be expected.

RELATION OF "MILD MOSAIC" TO THE NECROTIC SYMPTOMS OF RED MOSAIC

The original description of "mild mosaic" was made by Bennett (1) for the variety Cumberland. He included the necrotic symptoms, except the dying of cane tips, under "mild mosaic". Later, he (2) revised this description and combined with red mosaic all phases of the necrotic symptoms, as well as certain types of the larger mottled areas shown in black varieties. However, he still retained the milder types of mottling under the name "mild mosaic", but suggested, because of the variability displayed, that "mild mosaic" might eventually be shown to consist of several distinct virus diseases.

A study of the correlations between all phases of "mild mosaic" and the necrotic symptoms of red mosaic in the several hundred Plum Farmer plants over a period of three years has shown that they are phases of the same disease (Table 4). No separation or constancy was found between small and large types of "mild mosaic" mottling on Plum Farmer. The correlation between all types of "mild mosaic" and red mosaic, as determined by necrotic symptoms, was that 2.4 per cent

TABLE 4.—RELATION OF "MILD MOSAIC" TO RED MOSAIC IN PLUM FARMER AND CUMBERLAND.*

	PLUM FARMER POPULATION (293 PLANTS)		CUMBERLAND POPULATION (131 PLANTS)	
	Number of plants	Per cent	Number of plants	Per cent
No Necrotic Symptoms of Red Mosaic Shown				
Healthy for 3 years	117	40.0	32	24.4
"Mild mosaic" for 3 years	—	2.4	37	50.4
"Mild mosaic" for 2 years	3		14	
"Mild mosaic" for 1 year	4		15	
Necrotic Symptoms of Red Mosaic Shown				
"Mild mosaic" present also	135	46.0	30	22.9
No "mild mosaic" present	34†	11.6	3	2.3

*All plants in a field that had 3 years' record of "mild mosaic" or red mosaic, or neither disease.

†Thirty-one of the 169 plants showing necrotic symptoms in 1929 had shown necrotic symptoms for 3 years and 140 of the 169 had shown such symptoms for 2 years. The 34 plants listed as showing no "mild mosaic" in 1929 were almost entirely plants dwarfed to the ground. Such plants in the Plum Farmer variety often do not show "mild mosaic".

of the plants with 3 seasons' record showed "mild mosaic" without distinguishable necrotic symptoms; and that 11.6 per cent of the plants showed necrotic symptoms without accompanying "mild mosaic", but of these practically all were severely dwarfed specimens. The above percentages were calculated for the entire population (293 plants) in which 117 plants (40 per cent) remained healthy and 169 plants (57.6 per cent) showed necrotic symptoms of red mosaic. It does not seem possible that such close correlations as these could exist over a 3-year period in this number of plants for two distinct diseases. Furthermore, it cannot be argued that "mild mosaic" is different in Plum Farmer and in Cumberland, because, at least the symptoms are identical and have exactly similar relations to weather conditions and to other growth factors.

In the same planting in which the above correlations were obtained in Plum Farmer, there were 131 plants of the variety Cumberland haphazardly interplanted which had dependable records for 3 years. The correlations in these Cumberland plants between "mild mosaic" and the necrotic symptoms of red mosaic were as follows: 50.4 per cent of the plants showed "mild mosaic" with no indications of necrotic symptoms and 2.3 per cent showed necrotic symptoms without any indication of "mild mosaic", the percentages being based on the entire population of 131 plants in which 32 (24.4 per cent) remained healthy and 30 (22.9 per cent) showed necrotic symptoms of red mosaic. The correlation

shown in Cumberland was not close, 25.2 per cent showing necrotic symptoms (22.9 per cent combined necrotic and mild symptoms) and 50.4 per cent showing "mild mosaic" but no signs of necrotic symptoms. This lack of more uniform correlation as compared with the variety Plum Farmer is believed to be explained by the resistance of Cumberland.

Cumberland is more resistant to red mosaic as shown by the necrotic symptoms. Most of the varieties of black raspberries correspond to Plum Farmer in susceptibility. Cumberland is an outstanding variety in its resistance. The necrotic symptoms, when shown, are more likely to be largely suppressed. In most cases only slight evidence is visible of the "water-soaked" or bluish areas on slightly dwarfed leaves. Roughly estimated, very few Cumberland plants develop marked necrotic symptoms, not over 10 per cent, while in a more susceptible variety like Plum Farmer about half of those showing necrotic symptoms show them markedly. The percentage showing marked symptoms will vary greatly with weather conditions. In 1930, in a large number of Plum Farmer plantings examined, almost every plant, young or old, which showed any type of "mild mosaic" showed, in addition, early in the season, easily detected necrotic symptoms. The correlation was much easier to determine in 1930 than is usually the case because of the earliness of appearance and strength of the necrotic symptoms. It was not found that necrotic symptoms were caused to appear in Cumberland to much greater extent in 1930 than in other seasons. Apparently, under the most favorable conditions, the necrotic symptoms remain largely suppressed.

Plantings examined in New York, Ohio, and Michigan in the early summer of 1930 substantiated the conclusion drawn from previous observations that "mild mosaic" and the necrotic symptoms of red mosaic in Cumberland appear to be distinct diseases because of the suppression of the necrotic symptoms in a resistant variety. These conclusions, it seems, are justified, since in a more susceptible variety, as Plum Farmer, there is a uniform correlation between "mild mosaic" and the necrotic symptoms, even tho in such a variety marked necrotic symptoms are suppressed but still recognizable in about one-half of a given population. It is recognized that this question should be finally determined by cross inoculations, using some variety which shows definite necrotic symptoms and giving due allowance for a reduction in the virulence of the virus.

SUMMARY

Five virus diseases are known in black varieties of raspberries, *viz.*, leaf-curl beta type, severe streak, mild streak, red (raspberry) mosaic, and yellow mosaic. In New York, red mosaic, yellow mosaic, and mild streak are commonly found in black raspberry plantings. Red mosaic is the most prevalent and destructive.

Yellow mosaic shows prominently in all varieties and thruout the season. The leaves are markedly yellow and distorted, and the entire plant is severely dwarfed and soon dies. The symptoms of mild streak are similar to those of severe streak but in greatly suppressed form. In certain seasons the symptoms of mild streak are suppressed to the extent that accurate detection is impossible. Red mosaic is expressed by two types of symptoms, *viz.*, mottling of the foliage (formerly called "mild mosaic") and by necrotic symptoms. Weather conditions determine to some extent the strength of both types of symptoms. The necrotic symptoms are greatly suppressed in a large percentage of the population of a susceptible variety and almost or entirely suppressed in all plants of a resistant variety.

The mottling symptoms in the foliage early in the season, known as "mild mosaic", were correlated with marked or suppressed necrotic symptoms of red mosaic in Plum Farmer. The lack of correlation between "mild mosaic" and the necrotic symptoms of red mosaic in Cumberland is believed to be due to the entire suppression of the necrotic symptoms in the majority of a population of this variety. "Mild mosaic" is considered to be a phase of red mosaic, actual proof of which will depend upon inoculation experiments.

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